Achieving Sustainability, Energy Savings, and Occupant Comfort

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ABSTRACT

Sustainability, energy savings, and occupant comfort are not mutually exclusive objectives, as buildings can be designed that incorporate all of these features. Sustainability is often defined as meeting the needs of the present without compromising the ability of future generations to do the same. Reducing the demand for energy produced from depletable resources and generating energy from renewable sources leaves more resources available for future use. Therefore, energy savings and sustainability go hand in hand. Occupant comfort can be maintained in conjunction with energy savings, and some sustainable practices enhance comfort. Properly planned and implemented construction programs can help ensure efficiently operating systems, reducing the consumption of valuable resources, while providing an acceptable indoor environment. The authors have more than 30 years combined experience working with Texas schools in mechanical, electrical, and plumbing engineering and design as well as energy management.

SUSTAINABILITY

The dictionary defines sustainability in terms of using a resource without depleting or permanently damaging it. Sustainability is often synonymous with "green building" and "high performance building". Broad definitions of these terms include environmental responsibility, resource efficiency, and occupant comfort along with a sense of well being. On the other hand, more narrow definitions may focus on only one design feature, e.g. energy efficiency.

Many of the additional clarifications of what constitutes sustainability, or green building, have come from the U.S. Green Building Council's LEED rating systems. According to LEED, sustainable building features include developing sites so as to minimally affect surrounding areas, using recycled or salvaged building materials, reducing water demand, providing energy without the use of fossil fuels, adequate ventilation, reduction of indoor pollutants, and thermal comfort.

ENERGY SAVINGS

Energy savings typically is meant to refer to a reduction in electric consumption. However, lowering the use of any fuel, e.g. natural gas, propane, etc., is also saving energy. Savings can be achieved directly - from reducing energy consumption of on-site equipment such as lighting, HVAC, and miscellaneous plug loads. It can also be accomplished indirectly. For example, using less water decreases energy consumption needed to treat and pump water to a facility.

Energy savings results from the way buildings are constructed, operated, and maintained. Sustainable building practices such as the installation of energy efficient lighting and heating/cooling systems, the use of natural lighting, and commissioning all can result in reduced energy consumption. Proper maintenance of equipment increases its expected life, improving performance and reducing energy use. Energy saving building designs need not result in reduced occupant comfort.

OCCUPANT COMFORT

Occupant comfort includes thermal comfort, visual comfort, and satisfaction with the overall indoor environment. Thermal comfort is influenced by ambient temperature, humidity, and air flow. All of these parameters can be regulated to maintain comfort while being energy efficient. Visual comfort includes adequate light levels and glare-free lighting. Energy efficient lighting and the use of natural light can both save energy and be pleasing to occupants when done correctly. Selection of lighting methods and the use of building materials and implementation of construction techniques that are considered sustainable may improve occupants' overall satisfaction with a space.

When one speaks of comfort in a space, they are generally referring to being the proper temperature. Too hot or too cold, and one quickly feels discomfort. Most complaints received from building occupants are regarding “improper” temperatures. Thermal discomfort can result from temperature settings being too high or too low, excess humidity, improper air flow, or malfunctioning equipment. High humidity levels can make a properly tempered space seem otherwise. Too much moisture causes a warm room to feel warmer than it actually is and also gives it a sticky feeling. ASHRAE Standard 55 outlines combinations of temperature and humidity that result in comfortable conditions for the majority of occupants.

A breeze outdoors on a hot summer day dissipates heat from the body, making one feel cooler. In the same way, proper air flow in a space circulates conditioned air, supplementing the cooling effect. Improper air flows that are too low can cause occupants to feel uncomfortable, even if temperature and humidity are within the acceptable range. In classroom settings, as a rule of thumb, air flows of approximately 0.9 to 1.5 cfm per square foot (4.5 to 7.5 L/s per square meter) of room area result in comfort to most people. At rates well above or below these levels, occupants may complain of feeling too little or too much air. A lack of air flow during the heating season may result in occupants feeling a lack of warmth, while too much air can make them feel chilled.

Occupant comfort also depends on a sense of satisfaction and well-being. Daylighting can contribute to these feelings of contentment, providing a link to the world outside. Occupants are able to determine time of day, observe weather conditions, and sometimes view the landscape as well, depending on the placement of the windows. Studies have indicated that daylighting is pleasing and may positively influence student performance and worker productivity.

Visual satisfaction is also a component of occupant comfort. If lighting is inadequate, excessive, or causes glare or eyestrain, occupants will be dissatisfied. Properly designed lighting, from both natural and electric sources, can provide pleasing visual conditions. The quality of lighting is just as important as the quantity. Even if lighting levels are adequate, poorly designed systems can diminish the quality of the indoor environment.

LESS ENERGY – OCCUPANT COMFORT

Reducing energy consumption while maintaining occupant comfort can be accomplished through energy-efficient equipment procurement, operation, and maintenance. A combination of all three potentially enhances energy savings even more.

In Texas, for example, cooling is the biggest consumer of energy in schools, accounting for about 40% of annual consumption. When purchasing air conditioning equipment, factors that can impact energy use are equipment type (chillers, DX units), size (tons), and efficiency (SEER, EER, IPLV). Chillers and DX equipment have different characteristics which may influence energy consumption. DX equipment typically offers more flexibility since units can be run only in areas where cooling is needed, whereas chillers must be operated when cooling is desired in any area. Although chillers can operate at part load values down to 20 %, this point is still likely more cooling than is needed for a small area. Energy codes and/or federal law prescribe the minimum efficiencies of air conditioning equipment that can be purchased and/or installed. However, an initial investment in higher efficiency equipment can result in energy saving over the life of the equipment. For example, federal law sets the minimum efficiency for air conditioners five tons and less at 13 SEER. Increasing the efficiency to 17 SEER potentially reduces energy usage by almost 25%. The additional cost of equipment would be approximately 12%, or $200 per ton. Utilization of higher efficiency equipment is unnoticeable to occupants. For a 3-ton unit, typical in a modern classroom setting, the payback would be about six to seven years (at an electricity cost of $0.12 per kwh).

How energy-using systems are operated can greatly impact energy savings. Giving occupants control of the temperature within in a narrow range of reasonable settings increases their comfort and saves energy simultaneously. Where occupants have access to an unlimited scale of settings, temperatures may be set unnecessarily low for cooling or high for heating. Whereas, if they have no ability to change the setpoint, there is likely to be an increase in complaints and tampering with room controls. A bandwidth of 4°F (2.2°C), 2°F (1.1°C) above and 2°F (1.1°C) below the desired setpoint temperature, has proven to be a good compromise to allow both occupant intervention and energy savings.

Setpoint temperatures are a big determinant of how much energy equipment will use. The greater the difference in the setpoint and the outdoor temperature, typically the more equipment will operate. For schools and similar facilities, each degree the cooling setpoint is above 72°F (22.2°C) saves approximately 1.5% on annual cooling energy costs. Similarly, for each degree above 68°F (20°C), annual heating energy costs are reduced roughly 1%.

Controls can range from the very simple, a wall thermostat, to sophisticated computer-based energy management control systems. Wall thermostats provide a means to turn air conditioning systems on and off and to maintain a preset room temperature. They are manual, requiring intervention by people to make any desired changes in equipment status or room temperature settings. Occupants are able to select temperatures anywhere within the range supported by the thermostat. However, sometimes staff turns thermostats to very high or low settings in a mistaken attempt to make areas cool or heat faster. Often, thermostats are left at these extreme settings for extended periods of time, which wastes energy and can damage equipment. Time clocks or programmable thermostats offer a simple means of turning equipment on and off at predetermined times. Energy management control systems (EMCS) combine the ability to manage both status and temperature. Units can be turned on and off at times to match the occupancy schedules of facilities. This reduces or eliminates instances where equipment is running when buildings are unoccupied. As previously noted, occupants can be given a range of room temperatures that they can choose. Rooms can also be brought to desired temperatures automatically before occupants arrive. Both of these functions eliminate the selection of energy wasting high or low setpoints. EMCS also can provide monitoring and diagnostics capabilities, allowing building operators to observe system functions and troubleshoot problems from a central or remote location.

Comfort need not be diminished just because occupants have less control over their room temperature settings. Staff can be given temperatures from which to select that still provide comfort to the majority of people. Complaints are not uncommon when systems offering less control of temperatures are introduced; however, objections usually decline over a relatively short period of time. EMCS can be used to manage setpoint temperatures and operating hours, which commonly reduces energy consumption by 10% or more. The capability to monitor system operation and performance allows operators to detect and potentially diagnose and fix problems earlier on. Corrections can be made before they adversely affect comfort or energy consumption.

Maintenance of HVAC systems can affect both occupant comfort and energy usage. The list of preventative maintenance checklist items for boilers, chillers, condensing units, pumps, motors, and fans is quite lengthy. Some items affect safety, some performance, others energy efficiency, and still others occupant comfort. The following are examples of items that potentially affect both comfort and energy efficiency:

- Changing filters regularly
- Verify correct belt tension and alignment
- Confirm proper damper operation
- Repair duct leaks
- Calibration of sensors

HVAC systems that are well-maintained tend to also provide a good indoor environment and use less energy when compared with systems that receive no maintenance.

Lighting is the second largest user of energy in Texas schools, accounting for about 20% to 25% of annual consumption. Lighting systems with electronic ballasts and T-8 lamps represented a 15% to 20% decrease in energy use over the previous generation of T-12 energy-saving lamps and electromagnetic ballasts. The latest generation of high-efficiency T-8 ballasts uses some 6% to 10% less energy than standard electronic ballasts. T-5 lamps, which are becoming more common, have many of the same energy characteristics as T-8 lamps.

As a result of utilizing electronic ballasts to save energy, visual comfort is improved. Electronic ballasts eliminated flicker problems associated with magnetic and electromagnetic ballasts.. T-8 and T-5 lamps have better color rendition, that is, accuracy with which they display colors. (Sunlight is said to render colors perfectly.)

Fixtures have been developed that take advantage of the characteristics of T-5 lamps, for instance. Their smaller diameter and tube wall brightness makes them suitable for indirect fixtures, some of which use fewer lamps than traditional T-8 fixtures. One such recessed, indirect volumetric fixture uses two T-5 lamps and gives off approximately the same amount of light as a recessed three-lamp T-8 troffer. The lighting produced is even and glare-free. Energy savings is about 20% over the three-lamp T-8 fixture.

Properly designed daylighting features (windows, skylights, etc.) can also provide visually pleasing lighting. Good window placement, brightness control, and even illumination are all key components of good daylighting. Daylighting features must also be designed so as not to allow excess solar gain and heat transmission, which increases the load on air conditioning. With intense summer sunshine and high ambient temperatures in Texas, this is a very important consideration.

Energy efficiency can be accomplished through the purchase of more efficient equipment, cost-effective operation of systems, and proper maintenance. All of these can be done without detriment to occupant comfort. In fact, occupant comfort may, in many cases, be enhanced.

SUSTAINABILITY – ENERGY SAVINGS

Energy savings and sustainability go hand in hand. Sustainability, as already mentioned, includes saving resources today so they will be available in the future. Currently, the majority of energy consumed in buildings comes directly or indirectly from the burning of fossil fuels. Most electricity in the U.S. is generated by power plants that burn coal or natural gas. Heating systems typically utilize natural gas, propane, or heating oil – all fossil fuel derivatives.

The use of fossil fuels can be reduced in two ways – cutting energy consumption or generating electricity from alternate sources, such as wind power or solar power. A combination of the two approaches is most plausible. Reducing energy usage has a more immediate effect. According to the July 2009 Monthly Energy Review from the U.S. Department of Energy, renewable energy sources (includes hydro, wood waste, biofuels, wind, geothermal, and solar) currently supply about 11% of our energy needs.

Currently, the main disadvantage of alternative energy sources is their high first costs. Wind turbines and photovoltaic (solar) panels, two of the more common distributed generation renewable energy methods for schools and similar facilities, cost several thousand dollars per kilowatt for materials and onsite installation.

Photovoltaic (PV) arrays can be successfully applied anywhere the sun shines, which is essentially everywhere. The amount of electrical energy they produce is proportional to their size and the intensity of the sunshine. Where the sunlight is more intense and shines longer hours, equipment produces more electrical energy. A PV array to power a small sign is only a couple of feet square; however, one to provide electricity for an entire elementary school might approach the size of a football field.

Wind turbines are more location dependent. They perform better in locations with higher average wind speeds and fewer ground obstructions, such as trees. Wind resource criteria developed by the Department of Energy show that areas of greatest wind potential in Texas are along the Gulf coast, in the Trans-Pecos region, and on the plains, essentially west of Fort Worth. Where wind speeds are too low, turbines typically do not turn fast enough to generate appreciable amounts of electricity.

SUSTAINABILITY – OCCUPANT COMFORT

In its broadest sense, the term “sustainability” is interchangeable with “green”, which denotes a holistic approach to building construction. Included in this concept are thermal comfort, visual comfort, and measures to improve indoor air quality.

As already mentioned, thermal comfort mainly has to do with ambient room temperature. As long as the temperature is within a range that produces comfort, occupants are generally satisfied. According to ASHRAE Standard 55, thermal comfort is generally accepted to have been achieved when 80% of occupants are satisfied. Those that are uncomfortable may need to wear heavier or lighter weight clothing or make other changes accordingly.

Humidity can also influence thermal comfort. A given temperature can feel very comfortable or very uncomfortable, depending on the humidity. Very low humidity can result in irritated skin and dry eyes. High humidity can cause rooms to feel stuffy, and warmer than they really are. In most parts of the country, high humidity is more a problem than low humidity. The spring and summer months can bring excess moisture that must be removed from indoor environments. Moisture removal is typically accomplished along with cooling from air conditioning systems. Properly sized units will, in most cases, remove excess moisture from buildings. Equipment that is oversized does not generally operate enough to adequately lower moisture content. The thermostat tends to become satisfied before humidity levels are satisfactorily lowered.

Proper ventilation is necessary for good indoor air quality. Outside air is needed to help dilute indoor contaminants and odors. ASHRAE Standard 62 and building codes allow a set amount of outside air (15 cfm per person in classrooms, for instance) or varying amounts based on room occupancy. Occupancy may be determined by carbon dioxide levels. Ventilation rates are modulated by a sensor placed in each space. A motorized damper is closed when CO_2 levels are low, indicating low occupancy. As levels, and occupancy rise, the damper opens to bring in more outside air. Typically, full open is reached at about 1100 ppm of CO_2. At levels above about 1100 ppm, indoor air quality is said to diminish, and rooms become stuffy, etc.

Outside air is needed for dilution of indoor air pollutants; however, especially in humid regions, it adds to latent loads. Cooling equipment must be sized accordingly. In a classroom setting, with a ventilation rate of 15 cfm per person, experience indicates that up to 20% of unit capacity is used to remove moisture from the outside air.

Some proponents of sustainable or “green” building advocate bringing in more outside air than is required by ASHRAE Standard 62 and building codes. LEED rating systems offer credits for ventilation rates exceeding ASHRAE Standard 62 requirements by at least 30%. In humid climates this potentially increases indoor humidity levels, if air conditioning units are not sized to handle the increased latent load. Larger equipment sizes result in higher electric demand and consumption.

Filters can be used to remove undesirable particulates as well as gaseous compounds from the air. Particulate filters, which remove dust, etc. are standard practice in HVAC systems. MERV, or minimum efficiency reporting value, is a number from 1 to 16 that indicates a filter’s efficiency at removing particles. The minimum filtration required by ASHRAE Standard 62 is MERV 6, which captures an average of 35% to 50% of particles in the airstream. MERV 6 filters are capable of removing pollen, dust mites, and fibers from the air. MERV 11 filters, for example, offer 85% to 95% efficiency and additionally capture some bacteria and fine dust. Removal of these types of particles from the indoor environment can reduce eye irritation, allergies, and respiratory problems. Gas phase filters can be used to remove unwanted vapors and odors that are too fine to be captured by particulate filters. Common gas phase filter materials include activated charcoal, silica gel, or porous clay. Most gas phase filters work by capturing gases in holes in their molecular structures, and some work through chemical reactions to bind the gas molecules. Currently, gas phase filtration is rather expensive to employ, discouraging its use on an across-the-board basis.

Daylighting is generally considered a sustainable building feature that can complement occupant comfort when correctly designed and applied. Skylights, clerestories, and windows that allow daylight into a space also permit those inside to view the world outside. They can check weather conditions or just take a moment to glance outside. Previous studies indicate that most people like having a source of daylight and an opportunity to see outside. One well-known study by the Heschong-Mahone Group concluded that students may perform better in daylighted classrooms.

However, daylighting must be properly designed to take advantage of daylight while not allowing sunlight to directly enter a room. Direct sunlight, as compared to daylight, can cause glare and excessive heating, The glass necessary to provide daylighting can permit unwanted heat gain. This effect can make air conditioning systems work harder, increasing energy usage, and make occupants seated near windows uncomfortable during the summer months. Therefore, glazings must be carefully selected and windows placed to minimize heat gain.

SUMMARY

Sustainability, energy savings, and occupant comfort can all be accomplished in the same facility. Sustainability includes using renewable energy sources, saving energy, and, depending on the breadth of the definition used, providing a comfortable and healthy indoor environment.

Energy savings can be achieved through proper maintenance, economical operations, and attentive procurement. Occupant comfort encompasses thermal satisfaction, visual ease, and an overall sense of wellbeing. Changing any aspect of building design involving one of the three main principles discussed – sustainability, energy savings, and occupant comfort – can affect one or more of the others, either positively or negatively. The goal of achieving all three can be attained within the same facility. That is, the three objectives are not mutually exclusive, and in many cases go hand in hand. Careful planning during the design phase, observing during the construction phase, and monitoring during the occupancy phase can ensure that the desired results are realized.